



# AMERICAN JOURNAL OF BOTANY

VOL. VII

JUNE, 1920

No. 6

## THE FUSION OF VENTRAL CANAL CELL AND EGG IN *SPHAGNUM SUBSECUNDUM*

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In a previous paper (1) the writer has followed in detail the development of the archegonium of *Sphagnum subsecundum* Nees. At that time the statement was made: "Usually just before fertilization the ventral canal nucleus disintegrates." However, in the early spring of 1917, while attempting to work out the details of fertilization, the interesting fact was uncovered that in the species here studied the ventral canal cell quite often does not disintegrate, but unites with the egg. It seems worth while, therefore, to report the facts in detail.

### MATERIAL AND METHODS

The area from which the material came is a grassy bog of about 20 acres near Mineral Springs, Indiana, 40 miles south of Chicago. In the summer and fall of 1912 this bog contained a sufficient amount of water to prevent fires from damaging the polsters of *Sphagnum* which were scattered throughout the bog. The material is probably dioecious, occurring generally in well defined polsters of one sex or the other. In a few cases mixed polsters were found, but in no instances were the sex organs found together in the same head or upon the same upright branch. The well defined differences in the appearance of male and female plants when the sex organs are approaching or have reached maturity have been stated in the previous paper, but will be repeated here for clearness.

The heads of antheridial plants are decidedly globose and show variations in color from yellow-brown to red-brown and sometimes almost black. Dissection reveals antheridia most of which are apparently at or near maturity. The heads of archegonial branches are less globose and have a somewhat flattened aspect on top. There is no unusual coloring except in the conspicuous bud in the center of the head. This bud varies in color from yellow-brown to red-brown and stands out in sharp contrast to the other portions of the head. An analysis shows archegonia, some young, others almost mature, as terminal structures on short side branches very close to the apex of the main axis, the coloring matter being in the peri-

[The Journal for May (7: 173-222) was issued June 16, 1920.]

chaetal leaves surrounding the organs. These well defined characters made field work a very simple and easy matter once they were determined.

In the latter part of November and during December, 1912, a careful survey of the bog was made, the best polsters being staked out with specially numbered stakes: one series for polsters of plants bearing only archegonia; another for those bearing only antheridia; and a third series for the areas in which the sexes were mixed together, where it was hoped to secure material for a study of fertilization. Notes on field and laboratory observations were kept, and from them the following facts are taken.

By the end of November, 1912, the weather had become very cold, the bog being frozen to the depth of several inches. Blocks of frozen plants together with the frozen mud on which they were growing were cut out with a hatchet and carried in to the laboratory for observation and study. There the blocks of plants were transferred to glass jars containing several inches of water. These jars were kept partially covered with glass plates. A dissection of the material this same evening (November 28) showed the following condition: The dehiscence of several antheridia was observed, the antherozoids being quite active, but most of the antheridia had not reached maturity. Many of the archegonia appeared to be mature, but it was difficult to find one in which the cap had burst and the pathway was open for fertilization. The ventral canal cell and the egg could be easily seen in most of the archegonia. At this time of the year they stand out as two well defined balls of cytoplasm in the center of the archegonium. These rounded protoplasts are frequently so clearly defined in the living material that they can be accurately measured with an ocular micrometer. The same is also true of the nucleus of each protoplast.

For the study of details a considerable amount of material was killed in a fluid made up as follows:

Chromic acid crystals.....	1 g.
Glacial acetic acid.....	1 cc.
Water.....	400 cc.

The following method was employed. Using a pair of forceps with sharp, slender points, the colored buds were snipped quickly and easily out of each head, and were either transferred immediately to the killing fluid, or, if too many sterile branches were included, the latter were cut away in water under a dissecting microscope, using needles for the purpose, and the bud was then put into the killing fluid. The numerous very short side branches bearing archegonia form a firm, compact bud which may be handled by this method without the slightest injury to the archegonia, which latter are well protected by the perichaetal leaves closely investing them.

During the period from December 1 to December 6 there were warm gentle rains. On the 6th a cold wave arrived, again freezing the bog. For the remainder of the month the weather was generally cold and dry with little snow. On December 26 a considerable amount of fresh material

was brought in from the field for further study. In general there was little change to be observed in the sex organs. Very few of the antheridia had dehiscent, and only occasionally was an archegonium to be found in which the egg had broken open. But in my notes there appears a fact interesting in the light of subsequent events. A number of cases were observed in which the ventral canal cell had disappeared. On this same evening a large amount of material was killed chiefly in the above mentioned fluid, using the method already described, and it is from this material that the facts here recorded were obtained. The alcohol-xytol method of dehydration and embedding in paraffin was used. The material was cut 5-6  $\mu$  in thickness on a rotary microtome. Safranin in combination with Licht Grün, and Heidenhain's iron-alum haematoxylin were used as stains.

It may be of interest to record briefly the further history of the bog and the material. Events were closely followed. The summer of 1913 was hot and very dry. The water level of the bog fell rapidly in the early summer and was never regained. In the spring of 1914 this bog and the country for several miles about were completely burned over by fires which swept the region. The Sphagnum was badly damaged but not entirely destroyed. However, subsequent fires seem to have completed the work of destruction. The writer revisited the area in the early spring of 1917 but was able to find only a few struggling plants where before there had been splendid polsters.

#### HISTORICAL

The appearance of the mature archegonium of Sphagnum seems first to have been described by Hofmeister (3), who represents a transverse wall as separating the ventral canal cell and the egg. The former cell is shown as smaller than the latter, this being especially true in comparing the protoplasts and the nuclei of the cells. The rounding off of the two protoplasts is clearly pictured.

A few years later Schimper (7) describes the "Keimzelle" of the fully developed archegonium as follows: "Diese sah ich bei Sphagnum immer ei- oder umgekehrt birnförmig, im letzteren Falle häufig den oberen engeren Theil von dem unteren weiteren durch eine Querwand gesondert." In his Plate 9, figure 13, he shows an archegonium with the protoplasts of egg and ventral canal cell widely separate. No wall is pictured, though he speaks of it in the text. Attention is called to the fact that the nuclei can be seen through the cells of the venter of the living archegonium. In regard to the "Keimzelle" Schimper says further: "Ich fand selbst Keimzellen, welche an beiden Enden eine Querwand zeigten (fig. 16)." Whether he observed three-celled embryos, or the result of what occasionally occurs in Sphagnum—the subsequent division of either the egg or the ventral canal cell—cannot be stated with certainty. That the three-celled structure is shown as though dissected from the archegonium would lead one to suspect the former case.

In 1872 Roze (6) draws very clearly (Pl. I, fig. 8) in a mature archegonium of *Sphagnum cymbifolium* the rounded protoplasts of the ventral canal cell and the egg, the latter being pictured as slightly larger than the former. Roze calls the protoplasts "gonosphères ou globules germinatifs" and refers to the two nuclei as "deux nucléoles primaires." He speaks of the persistence of the two globules (protoplasts) which he says remain up to fertilization, a condition that appears to be peculiar to *Sphagnum*. He finds the same characteristics in the archegonia of *Sphagnum subsecundum* and *S. acutifolium* as given above for *S. cymbifolium*.

In 1887 Waldner (8), studying the development of the sporophyte of *Sphagnum*, pictures (Pl. II, fig. 1), according to his explanation of the plates, a longitudinal section of a mature archegonium of *Sphagnum acutifolium* Ehrh. The egg is shown as distinctly egg-shaped, occupies the whole of the venter, and contains a large nucleus with a distinct nucleolus. A fertilized egg is also pictured (Pl. II, fig. 2), but since no adequate description is given of the details one is left in doubt as to the objects figured.

In 1897 Gayet (2) describes the egg of a mature archegonium as a large elliptical cell, being elongated in the direction of the axis of the archegonium. The nucleus is almost spherical and possesses always two nucleoli. The ventral canal cell is described and figured as biconvex.

In 1915 the writer (1, pp. 48, 49) gave the following description of events in the venter of a maturing archegonium: "The ventral canal nucleus produced by this division [*i.e.*, of the ventral cell] is peculiar, being only a trifle smaller than the egg [nucleus]; and is remarkable in that it is regularly persistent and behaves for a time just as does the egg. Not long after the division into ventral canal cell and egg the canal row begins to disintegrate (this process having a variable beginning, though quite often acropetal), but not so the ventral canal cell. Its cytoplasm begins to condense about the nucleus (the same process occurring about the egg), and soon we have in a mature archegonium the appearance of two eggs separated by a wall. Later the cytoplasm about each of these two nuclei becomes markedly condensed and rounded off and may be easily observed in the living material. Still later the wall between the two cells breaks down and the nuclei, each as the center of a ball of cytoplasm, come to lie near together in the venter of the archegonium. . . . Double venters (fig. 42), unequal division of the venter, the ventral canal nucleus larger than the egg (fig. 43), ventral canal nucleus the same size as the egg (fig. 44), and multiple eggs (fig. 45) are not of rare occurrence."

In 1916 Melin (5, pp. 300, 301) says: "Das Resultat [*i.e.*, of the division of the ventral cell] sind zwei Zellen die gewöhnlich ungefähr gleich gross sind. Manchmal kann die obere, die 'Bauchkanalzelle,' etwas kleiner als die untere, die Eizelle, sein. Beide runden sich bald ab, und wir erhalten zwei kugelförmige Zellen, die morphologisch so gleichartig sind, dass meiner Ansicht nach kaum ein gültiger Grund besteht, sie mit verschiedenen Namen

zu beschreiben, weshalb ich sie beide Eizellen nenne. . . . Jede der beiden Eizellen hat einen grossen ziemlich chromatinarmen Kern mit deutlichem Nucleolus; der Kern ist von ungefähr gleichförmigen Plasma umgeben. Bald verschwindet die Zellwand zwischen ihnen, und sie liegen nun frei in der Hohlhöhle."

The fusion of the ventral canal cell and the egg has been reported but once in the Musci. In 1908 J. and W. Docters van Leeuwen-Reijnvaan (4) published a remarkable article on the sexual process and spermatogenesis in several species of *Polytrichum*. Briefly stated their results are as follows: In the gametophyte generation there are six chromosomes, which is also the number in the cells of the antheridium. But in the final division in the antheridium a reduction process takes place so that each anthrozoid receives three chromosomes. In the archegonium the division of the ventral cell produces a ventral canal cell and an egg which are equal in size. During this division a reduction process is also said to occur so that each of these cells receives three chromosomes. The protoplasts of the ventral canal cell and the egg fuse while the neck of the archegonium is still closed. After the cap breaks open this fusion cell is fertilized by two anthrozoids. In this manner the sporophytic chromosome number is restored.

In 1913 Walker (9) published the results of his study on the behavior of the egg and the ventral canal cell in *Polytrichum formosum* and *P. commune*. More than one hundred archegonial rosettes were sectioned but no case of a fusion could be found. Walker thinks the appearance of fusion of the ventral canal cell and egg reported by the van Leeuwen-Reijnvaans is due to their method of fixation.

#### DEVELOPMENT OF VENTRAL CANAL CELL AND EGG

The ventral cell of *Sphagnum subsecundum* generally divides late into ventral canal cell and egg. The division of cells in the neck is almost if not quite complete when this division occurs. The ventral canal cell is not only persistent but remarkably variable in size. As a very general statement one may say that this cell and its nucleus are a trifle smaller than the egg and the egg nucleus (figs. 2, 8). However, the exceptions are numerous. Often the two are identical in size both as regards the protoplasts and the nuclei (figs. 3, 4), while more rarely the ventral canal cell is larger than the egg in both of these respects (fig. 9).

Shortly after the division of the ventral cell the cells of the canal row begin to disintegrate, but this process has not as yet been found to affect the ventral canal cell. The protoplast of this cell begins to round off, the same process having begun in the egg, the wall between the two cells breaks down, and we have the appearance of two well rounded eggs which soon come more or less in contact in the venter of the archegonium (figs. 3, 8, 9). About this time there may appear, especially in the upper portions of the venter, more or less faintly staining bodies which probably take their origin

from the disintegrated canal cells above. Sometimes these bodies lie close to the ventral canal cell (figs. 3, 8). A rare exception is shown in figure 4 in which a body from the neck has apparently joined itself to the protoplast of the ventral canal cell.

#### THE FUSION OF THE PROTOPLASTS

As illustrated by figures 4, 5, and 6, the protoplasts unite completely. This fusion is followed later by the union of the nuclei. Unfortunately the killing agent employed, while giving excellent morphological results and little plasmolysis, is not very satisfactory from a cytological standpoint, hence the details of chromatin behavior cannot be accurately reported. In general the chromatin of the two nuclei appears to be more or less intermingled. There is no tendency for each mass to remain distinct.

Every nucleus of *Sphagnum subsecundum* which has been observed thus far, with the exception of that of the fusion cell here described, whether it be of the gametophyte or of the sporophyte generation, is characterized by one conspicuous well-rounded nucleolus. The fertilized egg may prove an exception, since its nucleus has not been seen in a satisfactory preparation. The only other exception is to be found in this fusion nucleus. No case has yet been observed in which the two nucleoli of ventral canal cell and egg have united, though such a condition would seem perfectly possible. In all the cases so far observed the fusion occurs while the neck of the archegonium is still closed. There is, therefore, no danger of mistaking this fusion nucleus for that of a fertilized egg.

#### THE DISINTEGRATION OF THE VENTRAL CANAL CELL

In the material studied, clear cases of the disintegration of the ventral canal cell have been found a number of times. There is no doubt that the ventral canal cell frequently disintegrates; but a summary of the large number of slides studied thus far shows that the number of cases of the union of the two cells about equals the number of cases in which it is certain that the ventral canal cell has disintegrated. In a large number of cases the ventral canal cell was still persistent and was more or less in contact with the egg, as illustrated in figure 3. Two cases were found in which the nucleus of the egg appeared to be degenerating, while that of the ventral canal protoplast just above it was very clear, and sharply defined.

#### DISCUSSION

It is evident from an examination of the literature quoted that the rounded appearance of the protoplasts of the mature archegonium is not due to the killing agent but is a condition which may be observed and even measured in living material. The average of a number of measurements of the diameters of living protoplasts compared with a like average of killed and stained protoplasts shows that there has been some contraction due to the killing, both in protoplasts and in nuclei, but the contraction is relatively

sion and could not bring about the facts which have been observed. Figures 1 and 2 show the exact amount of plasmolysis due to killing and fixing.

Furthermore, I am unable to believe that the technique employed is responsible for the fusions. Using the same methods described in this paper I killed at various times in the fall of 1913 large amounts of *Sphagnum* for study of the development of the archegonium. In no cases could be found the slightest trace of injury to the sex organ at any stage of its development. No canal cells were ever observed in the venter, and only after the disintegration of the canal row did any of the contents of the neck begin to make their appearance in the venter. At a later time this disintegrated matter fills the venter with a slimy mucilaginous mass which makes the study of fertilization extremely difficult.

Still more important evidence that the technique is not responsible for the facts is that it is possible to demonstrate *stages* in the fusion of the protoplasts and the nuclei. Not only that, but on a slide from a single head appear archegonia showing the following conditions: (1) Protoplasts of the ventral canal cell and the egg not in contact. (2) Protoplasts have fused, but nuclei, while in contact, are still separate and distinct. (3) Protoplasts and nuclei have fused completely.

It seems hardly reasonable to believe that the technique could bring about the appearance of these varying stages in a single head.

Insofar as the writer is aware, the archegonium of *Sphagnum* is unique among the Musci in that it comes to maturity in the late fall, withstands the severity of winter, and the egg is fertilized in the early spring. It undergoes great changes in temperature in the alternate freezing and thawing of certain winters; and when snow is absent and the temperature is low it is subject not only to freezing, but no doubt to considerable drying as well. It may be that these severe external conditions furnish the stimulus which brings about the fusion of the protoplasts.

As yet I am unable to make any statement in regard to the behavior of the fusion nucleus. Whether it may develop directly into a sporophyte, whether or not it is capable of being fertilized, and whether or not this fusion is peculiar only to the species here studied—all these questions must await further work.

#### SUMMARY

1. The ventral canal cell of *Sphagnum subsecundum* is regularly persistent, and variable in size.
2. The protoplasts of ventral canal cell and egg round off and, the wall between the two disintegrating, they lie near together in the venter of the archegonium.
3. In material killed in the latter part of December a number of cases of the fusion of these protoplasts have been found.
4. The fusion of the protoplasts is followed by the fusion of the nuclei.
5. Undoubted cases of the degeneration of the ventral canal cell have also been found.



6. Occasionally the egg may degenerate, while the protoplast of the ventral canal cell remains functional.

7. Further work is needed to determine how general this condition is in other species of *Sphagnum*, and to follow the history of the fusion nucleus.

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#### EXPLANATION OF PLATES

All figures were drawn at table level with the aid of a camera lucida, using Spencer ocular 10 x and 1.5 mm. oil immersion objective. Being reduced one half in reproduction, they show a magnification of approximately 1000 x.

#### PLATE XIV

FIG. 1. Ventral cell of an archegonium having eight neck canal cells. Peculiarly shaped plastids in the cytoplasm.

FIG. 2. Ventral canal cell and egg still separated by a wall, showing the difference in size of the two nuclei. Contraction of the protoplasts is probably due in large part to plasmolysis.

FIG. 3. Wall has disintegrated, protoplasts have rounded off and are lying in contact in the venter. Nuclei and protoplasts practically identical in size.

FIG. 4. The two protoplasts in closer contact but outline of each distinct. Disintegrated material from canal row in contact with upper protoplast.

FIG. 5. Protoplasts have completely fused. Nuclei in contact, but each distinct.

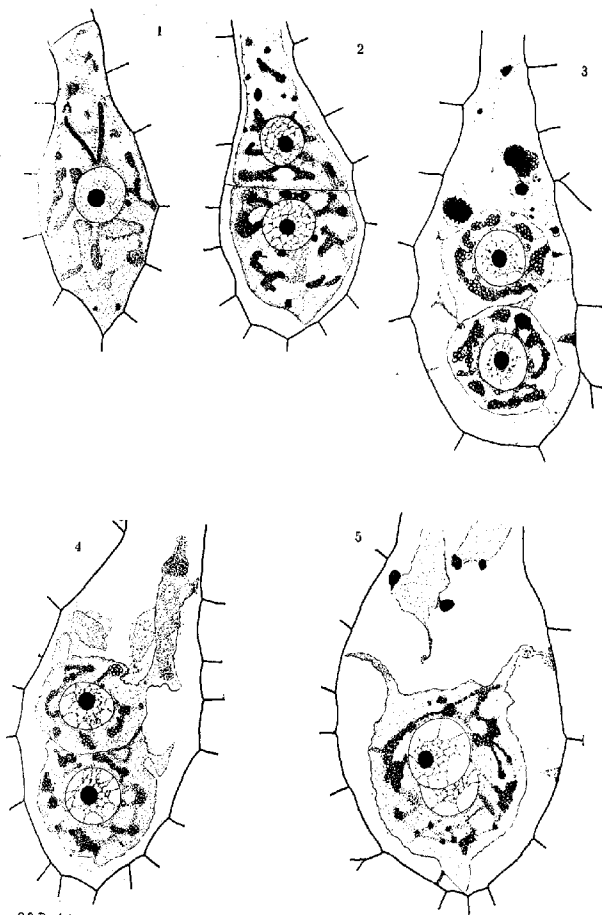
#### PLATE XV

FIG. 6. The fusion of protoplasts and nuclei completed. Mucilaginous matter beginning to appear about the protoplast.

FIG. 7. The disintegration of the ventral canal cell. Only a blurred mass remains.

FIG. 8. The rounded protoplasts. That of the ventral canal cell is smaller and has a smaller nucleus than the egg.

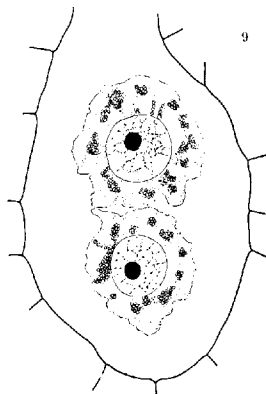
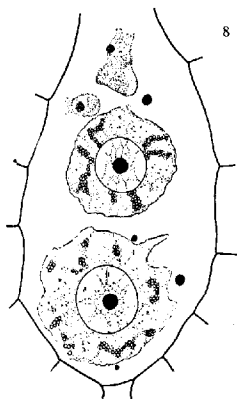
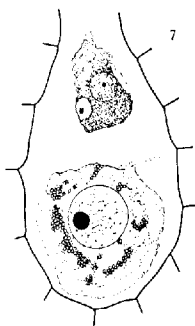
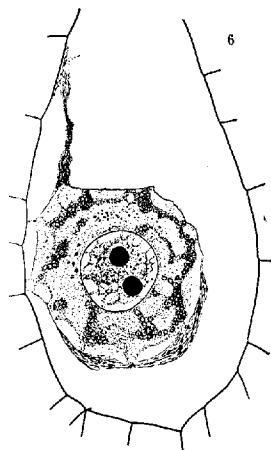
FIG. 9. Protoplast of the ventral canal cell is larger and has a larger nucleus than the egg.



G. S. B. del.

BRYAN: FUSION IN SPIROGYRA.





G.S.B., del.

BRYAN: FUSION IN SPHAGNUM.



# THE GEOGRAPHICAL DISTRIBUTION OF NORTH DAKOTA PLANTS

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The fact that North Dakota is only partially included within the limits used by eastern and western manuals, and that its northern boundary is also that of the United States, makes the composition and distribution of its flora a question of considerable interest. The present paper is offered as a preliminary analysis of our knowledge of the subject. It is based upon the records published by Bergman (3)<sup>1</sup> and upon the writer's observations made during occasional visits to nearly all parts of the state in the years 1910 to 1919. The number of vascular plants found within the state as listed by Bergman is 966. This is by a conservative limitation of species. Lunell (8), using narrow specific limits, lists about 1,300. It is thus seen that the number is small as compared with that of other states. This is probably due to a comparative lack of diversity of conditions, as there is no unexplored area which might add materially to the list.

To a botanist unfamiliar with the plants west of the range of the eastern manuals, the first feature of interest is the western plants. To the writer it has always seemed that the most natural limit of the western forms is the Missouri River in the southern part of the state and a line continued across the state in the direction of its course there, which would be about longitude 100° 30' to 101° 30'. A few of the western forms extend eastward as far as the Sheyenne River. A preliminary division into general groups according to the distribution of the plants in the state gave the following results:

I. Eastern; not west of Red River, Devil's Lake, or Turtle Mountains. . . . .	25%
II. Eastern; reaching the Missouri River. . . . .	10%
III. Western; west of the Missouri River. . . . .	11%
IV. Western; extending east to the Sheyenne River. . . . .	8%
V. Cosmopolitan. . . . .	30%
VI. Introduced. . . . .	16%

These figures are somewhat unsatisfactory, especially as to the second group, this being not well separated from the first. There is an apparent lack of records from the southern two thirds of the state from Jamestown west to the Missouri River. It is evident, however, that the western element is comparatively small. A more critical study of some of the principal families and orders with regard to their North American distribution shows the following results when grouped as in the preceding list. The number of species included in eastern (10) and Rocky Mountain (4) manuals is

<sup>1</sup> The nomenclature and arrangement of his work is followed in this paper.

added to show whether the families are better represented in the east or in the west.

TABLE I. *North American range of North Dakota plants*

	I	II	III	IV	V	VI	Total	N. E. U. S.	Mt.
<i>Ranunculaceae</i> .....	2	6	4	0	16	1	29	93	89
<i>Brassicaceae</i> .....	2	1	4	1	15	23	46	102	88
<i>Scrophulariaceae</i> .....	2	1	2	1	15	3	24	115	21
<i>Boraginaceae</i> .....	0	1	3	1	5	5	15	49	67
<i>Lamiaceae</i> .....	4	0	1	0	12	4	21	119	28
<i>Rosaceae</i> .....	4	4	4	5	14	1	32	214	94
<i>Fabaceae</i> .....	0	3	7	5	20	10	51	166	91
<i>Asteraceae</i> .....	25	7	19	2	53	12	118	428	493
<i>Liliates</i> .....	8	3	5	0	12	1	29	174	62
<i>Cyperaceae</i> .....	6	2	2	1	48	0	59	333	99
<i>Poaceae</i> .....	18	0	10	3	64	21	116	378	266
Total.....	77	28	61	19	274	81	540		
Percent.....	14	5	11	4	51	15	—		

In table I, column I includes only the strictly eastern plants; such species as are found only in the eastern part of the state but occur in the western United States or Canada are placed in column V. Columns II and IV are similarly affected. Various difficulties arise in such a compilation, chiefly through incomplete records. The statements of distribution as given in the manuals are frequently insufficient, and original or detailed records must be consulted. For general distribution chief reliance has been placed upon the statements of Rydberg (11).

#### THE WESTERN PLANTS

These are quite conspicuous in early spring on the hills, where we find such plants as: *Phlox Hoodii*, *Mertensia lanceolata*, *Viola Nuttallii*, *Orophaca caespitosa*, *Potentilla concinna*, and *Carex filifolia*. In late spring and early summer are found: *Paronychia sessiliflora*, *Eurotia lanata*, *Eriogynum flavum*, *E. mulliceps*, *Chamaerhodos erecta*, *Thermopsis rhombifolia*, *Astragalus pectinatus*, *Pentstemon cristatus*, *P. angustifolius*, and *Oreocarya glomerata*; on flats or gentle slopes below the hills, *Musineon divaricatum* and *Lomatium foeniculaceum*. On bare clay buttes in the "Bad Lands" and adjacent territory, *Pachylophus caespitosus* and *Chrysothamnus graveolens* are striking plants. The northern sides of many buttes are covered on the upper parts with *Juniperus horizontalis*, this being one of the plants which is absent in the eastern part of the state although it ranges to the Atlantic coast. *Artemisia cana* is a conspicuous low shrub on the hillsides and flats below; this is the nearest approach to "sage-brush," as *A. tridentata* has been collected only at one point (Medora).

Some species are reported only from the extreme western part of the state, such as:

<i>Alpinum bicolor</i>	<i>Kentrophyta montana</i>
<i>Physaria didymocarpa</i>	<i>Sideranthus grindelioides</i>
<i>Stanleya pinnata</i>	<i>Pyrrocoma lanceolata</i>
<i>Carobatus vermiculatus</i>	<i>Stenotus armerioides</i>
<i>Oronhia micrantha</i>	<i>Townsendia exscapa</i>
<i>Gilia congesta</i>	<i>Calochortus Nuttallii</i>
<i>Phacelia leucophylla</i>	<i>Juniperus communis</i>
<i>Homalobus caespitosus</i>	<i>Juniperus scopulorum</i>

Others, as before noted, extend eastward to the Shenyenne valley although less common eastward. Among these are: *Viola Nuttallii*, *Atriplex Buckleyana*, *Chamaerhodos erecta*, *Astragalus racemosus*, *A. bisculatus*, *Lomatium foeniculaceum*, and *Carex filifolia*.

The western plants belong to the great plains area, ranging chiefly from Nebraska to Saskatchewan. A few, such as *Gilia congesta*, *Pentstemon angustifolius*, *Hedeoma nana*, *Kentrophyta montana*, and *Picradenia pumila* seem to have a rather limited range (Colorado, Wyoming, Utah). Many extend as far south as New Mexico (see lists on later page), while the following go west into the Pacific coast states:

<i>Ranunculus glaberrimus</i>	<i>Rhus trilobata</i>
<i>Delphinium bicolor</i>	<i>Gaertneria acanthicarpa</i>
<i>Arabis Holboellii</i>	<i>Erigeron pumilus</i>
<i>Atriplex confertifolia</i>	<i>Pyrrocoma lanceolata</i>
<i>Navaretia minima</i>	<i>Artemisia cana</i>
<i>Allocarya scopulorum</i>	<i>Artemisia dracunculoides</i>
<i>Phacelia leucophylla</i>	<i>Artemisia tridentata</i>
<i>Mertensia lanceolata</i>	<i>Crepis occidentalis</i>
<i>Potentilla multisecta</i>	<i>Calochortus Nuttallii</i>
<i>Chamaerhodos erecta</i>	<i>Eriocoma cuspidata</i>
<i>Lavauxia brachycarpa</i>	<i>Poa Buckleyana</i>

#### THE EASTERN PLANTS

Species found along the Red River and not extending into western North America are:

<i>Actaea spicata</i>	<i>Leplandra virginica</i> (rare)
<i>Aquilegia canadensis</i>	<i>Penthorum sedoides</i>
<i>Clematis virginiana</i>	<i>Silphium perfoliatum</i>
<i>Anemone quinquefolia</i> (rare)	<i>Aster sagittifolius</i>
<i>Menispermum canadense</i>	<i>Allium tricoccum</i>
<i>Viola conspersa</i> (rare)	<i>Uvularia perfoliata</i>
<i>Caulophyllum thalictroides</i>	<i>Uvularia grandiflora</i>
<i>Sanguinaria canadensis</i>	<i>Trillium cernuum</i>
<i>Xanthoxylum americanum</i>	<i>Festuca nutans</i>
<i>Corylus americana</i>	<i>Oryzopsis melanocarpa</i>



Others, which occur only in the eastern part of the state, range west through Canada or are found in the Rocky Mountain region of the United States. Such are:

<i>Anemone virginiana</i>	<i>Petasites sagittata</i>
<i>Impatiens biflora</i>	<i>Vagnera racemosa</i>
<i>Rhamnus alnifolia</i> (rare)	<i>Disporum trachycarpum</i>
<i>Heliopsis scabra</i>	<i>Carex Deweyana</i>
<i>Moldavica parviflora</i>	<i>Scolochloa festuacea</i>
<i>Lathyrus palustris</i>	<i>Hystrix Hystrix</i>
<i>Lathyrus venosus</i>	<i>Dryopteris cristata</i>
<i>Meibomia grandiflora</i>	<i>Matteucia Struthiopteris</i>

#### EASTERN LIMITS OF PRAIRIE PLANTS

Many species common to the hills and higher prairie west of the Red River valley extend eastward into the prairie region of western and southwestern Minnesota. Upham (12) lists about 100 species which reach their eastern limits there. Most of these are common prairie plants in North Dakota, although absent from the lower ground of the valley or found only in certain places as upon old lake beaches and introduced with gravel on railroad grades. Such are:

<i>Malvastrum coccineum</i>	<i>Cymopterus acaulis</i>
<i>Asclepias speciosa</i>	<i>Gutierrezia Sarothrae</i>
<i>Pentstemon albidus</i>	<i>Chrysopsis villosa</i>
<i>Castilleja sessiliflora</i>	<i>Sideranthus spinulosus</i>
<i>Meriolix serrulata</i>	<i>Brauneria angustifolia</i>
<i>Gaura coccinea</i>	<i>Ratibida columnaris</i>
<i>Lepargyrea argentea</i>	<i>Gaillardia aristata</i>
<i>Anogra pallida</i>	<i>Artemisia frigida</i>
<i>Lomatium orientale</i>	

Others, associated with these, occur much farther east, as: *Erysimum asperum*, *Eleagnus argentea*, and *Aster plaromicoides*.

#### LIFE-ZONE DISTRIBUTION

As shown by the map (fig. 1), North Dakota lies almost entirely within the Transition Life Zone, the Canadian approaching closely on the north-east, the Upper Austral<sup>2</sup> on the south and west. Of the Transition Zone, Merriam (9) has stated that it is "as a whole, characterized by comparatively few distinctive animals and plants, but rather by the occurrence together of southern species which here find their northern limit, and northern species which here find their southern limit."

<sup>2</sup> No attempt is made in this paper to distinguish between a humid and an arid portion of these zones. Sonoran as referred to on later pages is included in Upper Austral.

## CANADIAN ZONE SPECIES

Pham (12) has given a list of about 75 northern species which reach the southern limit in the basin of the valley of the Red River of the North, but very few of these are known in North Dakota. The few Canadian

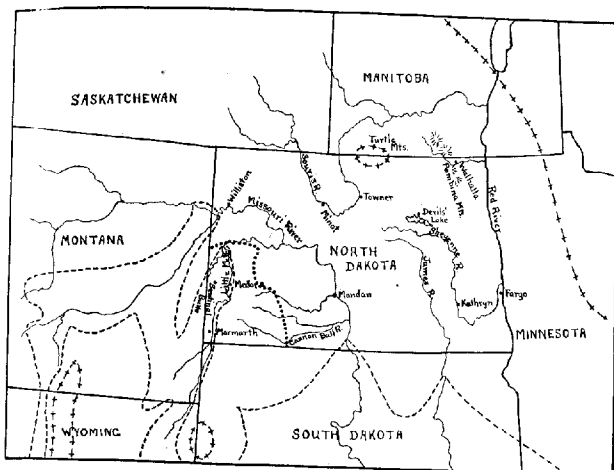


FIG. 1. Sketch map of North Dakota and adjoining states showing localities mentioned and life-zone boundaries as given by United States Biological Survey. + + + lower limit of Canadian Zone; — upper limit of Upper Austral Zone (Transition Zone between); . . . southern limit of glaciated area in North Dakota.

Zone plants which occur in the state are found in the Turtle Mountains and Pembina Mountains (as far south as Milton), these being outlying points cut off from the body of the zone by a distance of 100 miles or more. The following species may be mentioned:

<i>Anemone Hudsoniana</i>	<i>Oxytropis deflexus</i>
<i>Corylus rostrata</i>	<i>Mitella nuda</i>
<i>Geranium Bicknellii</i>	<i>Ribes triste</i>
<i>Polygala Senega</i>	<i>Circaea alpina</i>
<i>Pyrola asarifolia</i>	<i>Lepargyrea canadensis</i>
<i>Arctostaphylos Uva-ursi</i>	<i>Cornus canadensis</i>

<sup>2</sup> According to the fourth provisional map (1916). Mr. Vernon Bailey, who has read the manuscript of this paper, writes that in a report on the mammals of North Dakota which he has about completed, he has extended the Upper Austral limit to the mouth of the Cannon Ball River and a little way up that river; also a little farther in the western valleys.

*Erigeron lonchophyllus*  
*Achillea multiflora*  
*Senecio eremophilus*

*Corallorhiza multiflora*  
*Cinna latifolia*  
*Avena Torreyi*

It is noteworthy that most of these are plants of wide distribution in North America except *Oxytropis*, *Avena*, and the three composites, which are western. Of the foregoing, *Anemone*, *Pyrola*, *Avena*, and *Erigeron* are recorded from Devil's Lake, the last-named only from there. Another touch of Canadian Zone plants is evident in deep ravines at Kathryn where *Pyrola secunda*, *Corylus rostrata*, and *Circaea alpina* have been found. *Oxytropis splendens* occurs throughout the northern part of the state, but not over 50 miles southward so far as known.

#### UPPER AUSTRAL SPECIES

This zone reaches the borders of the state at three points, viz.: the valley of the Missouri River on the south and northwest and that of the Little Missouri on the southwest. *Pentstemon grandiflorus* is common along the Missouri River at least as far as Mandan and up the Cannon Ball for some distance; *Talinum parviflorum*, *Eriogynum annuum*, *Specularia perfoliata*, *Erigeron caespitosus*, *Leptilon divaricatum*, *Munroa squarrosa*, *Diplachne fascicularis*, and *Pellaea atropurpurea* are known only from the lower Missouri; *Atriplex confertifolia*, *Sarcobatus vermiculatus*, *Abronia micrantha*, and *Astragalus gracilis* (Marmarth, Stevens in 1918), only from the Little Missouri. *Clematis ligusticifolia*, *Psoralea lanceolata*, *Aster pauciflorus*, and *Oryzopsis micrantha* are known from the upper Missouri as well. (For further notes on austral species see under "Comparison with the Flora of New Mexico.")

A considerable representation of austral forms is found also in the southeastern part of the state where the Sheyenne River turns northward. From here only is known *Bouteloua hirsuta*; other noteworthy species are: *Pentstemon grandiflorus*, *Mimulus Geyeri*, *Bacopa rotundifolia*, *Verbena stricta*, *Lythrum alatum*, and *Cenchrus tribuloides*. To this list Mr. Reynold Shunk added in 1917: *Euonymus atropurpureus*, *Sicyos angulatus*, and *Cyperus diandrus*.

#### SAND DUNE SPECIES

Two small areas of drifting sand occur in the state, one at the locality last mentioned, the other near Towner. From these only are recorded: *Euphorbia Geyeri*, *Petalostemon villosus*, *Lygodesmia rostrata*, *Cyperus Schweinitzii*, and *Redfieldia flexuosa*. From near Towner we have *Cycloloma atriplicifolium* and *Andropogon Hallii* which do not elsewhere in the state occur so far north.

#### RECORDS OF SPECIAL INTEREST

At Fargo there is a slight intermingling of northern and southern species. *Lappula americana*, which occurs there, must reach nearly its southeastern

limit in that region; it is reported as far as Nebraska (11) and Iowa (10) but from Minnesota for the first time in 1901 (13) from farther north. On the Minnesota side near Fargo is a colony of *Petasites sagittata* which seems to be the most southeastern point known for that species. *Pyrola elliptica* and *Gaultheria procumbens* are found in the same piece of aspen woods. *Thysanotus*, an austral species, has been found in quantity at Wild Rice which is ten miles farther south. *Celtis occidentalis*, which extends irregularly farther north, is frequent at Fargo.

At Walthalla there is a typical butte, said by Willard (14) to be perhaps the easternmost in the United States. Upon this grow a number of plants which are otherwise found only in the western part of the state, such as *Eriogonum flavum*, *Artemisia cana*, and *Juniperus horizontalis*. In the woods of the river near by occur a number of woodland plants which are known from no other locality in the state: *Mitella nuda*, *Rhamnus alatifolia*, and *Asarum acuminatum*, which are purely eastern species; also *Cardamine pennsylvanica*, *Petasites sagittata*, *Leptorchis Loesselii*, *Carex leptalea*, and *Cinna latifolia*, which also occur in western North America.

From Sentinel Butte and Medora only, is recorded *Dasiphora fruticosa*. This is a Canadian to Arctic Zone plant of wide distribution and these stations are perhaps to be regarded as cut off from the Black Hills region, but it seems strange to find this plant where there is a prominent representation of austral forms. Likewise, *Juniperus horizontalis*, which is mainly a Canadian Zone species, is common on the buttes and hills along the Missouri and westward.

The distribution of the two species of lupine (*Lupinus argenteus* and *L. pusillus*) extends, as far as known, about to the southern limit of the glaciated area as indicated by Leonard (7).

#### INTRODUCED SPECIES

Of the introduced species, the abundance of Brassicaceae and Chenopodiaceae (including such recent introductions as *Erucastrum Pollichii*, *Camelina dentata*, and *Axyris amaranthoides*), and the scarcity of Polygonaceae (*Rumex* spp. and *Persicaria* forms) and of Euphorbiaceae are noteworthy. Of Compositae, *Carduus arvensis* and *Sonchus arvensis* are by far the most important.

The observations made by Upham (12) thirty years ago are interesting in comparison with present conditions. He notes of *Thlaspi arvense*: "long established and very abundant in the vicinity of Winnipeg, recently spreading into Minnesota and North Dakota." Of *Taraxacum officinale*: "frequent along roadsides, in pastures, etc., about Winnipeg and plentiful at the west end of the main street in St. Vincent; generally rare or absent throughout the Red River Valley." Both of these plants have since become particularly abundant in the valley. He also notes the absence of *Ambrosia trifida* (native weed) from the district about Langdon where it is

absent still. *Sonchus arvensis* he does not mention, it having been introduced in Manitoba a few years later and being now common through the valley and spreading farther.

*Neslia paniculata* and *Camelina sativa* seem to be restricted mostly to the northeastern two or three counties, *Camelina dentata* being widely distributed in flax. Certain Poaceae are especially abundant and characteristic: *Avena fatua*, *Hordeum jubatum*, and *Agropyron repens*. *Chenopodium glauca*, *C. viridis*, *Echinochloa crus-galli*, and *Panicum capillare* are also very abundant but perhaps less characteristic. *Syntherisma sanguinalis* is repeatedly introduced in southern-grown millet seed but has not been collected in the state even in adventive condition. *Plantago lanceolata* has been collected a few times but apparently does not become established.

#### COMPARISON WITH THE BIOLOGICAL SURVEY REPORTS

Considerable difficulty has been found in trying to correlate the distributional data with those of previous publications dealing with life zones. The Rocky Mountain region has been described in considerable detail, but in the plains region, as noted by Cary (6), the zone limits are less well marked. Trees have been used to a great extent in indicating the boundary lines of the zones, and North Dakota is especially lacking in trees.

*Pinus scopulorum* is mentioned by Cary (5) as "the characteristic Transition tree," but in North Dakota it is found only on the hills in the extreme southwestern part of the state where the Austral Zone invades the river valleys. *Populus tremuloides*, according to the same author, "is perhaps the best characterizing tree of the Canadian Zone" in Wyoming (6). He also mentions it as "restricted to the Canadian Zone" in Colorado, while Bailey (2) lists it for the same in New Mexico. Apparently it is most abundant in this zone east of the mountains, but it is common through the Transition Zone and extends half way through the Upper Austral in the Mississippi Valley region. *Quercus macrocarpa* is noted as growing in the Transition Zone in Wyoming (6), but in the Mississippi Valley region where it is more abundant it extends from the Canadian southward well into the Lower Austral.

Of the trees and shrubs listed by Cary as Upper Sonoran in Wyoming, at least *Salix amygdaloides*, *S. fluviatilis*, *Atriplex argentea*, *Amorpha nana*, and *Gutierrezia sarothrae* are common in North Dakota Transition, while the same may be said of fully one fourth of the "herbaceous plants." In the same paper *Psoralea argophylla* is listed as Transition, although it is common on the plains through Upper Austral; *Actaea rubra*, *Stevensia ciliata*, and *Heracleum lanatum*, listed as Canadian, are common in North Dakota Transition.

## COMPARISON WITH THE FLORA OF NEW MEXICO

The fact that Wootton and Standley (15) have indicated the zonal distribution for practically all the species found in New Mexico has made it desirable to examine the distribution of such North Dakota plants as occur there. A tabulation shows that 418 of the 966 North Dakota plants (43.3%) are recorded in New Mexico. Of these the distribution in the latter state is:

Introduced.....	68	Transition.....	77
Aquatic or not stated.....	42	Transition to Canadian.....	15
Lower Sonoran.....	3	Transition to Hudsonian, etc.	3
Upper Sonoran.....	126	Canadian or higher zones....	11
Sonoran to Transition.....	73		

(Of those listed here as Upper Sonoran, many range also in Lower Sonoran, but only their northward distribution is considered here.)

Fourteen of the Sonoran species have been mentioned in a preceding paragraph as entering North Dakota at one or more of the three points where that zone touches the state. About three fourths of the number extend into Transition, and these it seems convenient to divide into two groups. The following seem to extend only part way into Transition (occasional over the area southwest of the Missouri or in the southern part of the state east of that river):

<i>Myosurus minimus</i>	<i>Gaertneria acanthicarpa</i>
<i>Polanisia trackysperma</i>	<i>Chrysothamnus graveolens</i>
<i>Euphorbia serpens</i>	<i>Stenotus armerioides</i>
<i>Euphorbia glyptosperma</i>	<i>Townsendia exscapa</i>
<i>Euphorbia Geyeri</i>	<i>Hymenopappus filifolius</i>
<i>Cycloloma atriplicifolium</i>	<i>Bahia oppositifolia</i>
<i>Eurotia lanata</i>	<i>Tetrameuris acaulis</i>
<i>Parietaria pennsylvanica</i>	<i>Helianthus petiolaris</i>
<i>Plantago Purshii</i>	<i>Tradescantia occidentalis</i>
<i>Acerates viridiflora</i>	<i>Yucca glauca</i>
<i>Solanum rostratum</i>	<i>Cyperus inflexus</i>
<i>Hedeoma nana</i>	<i>Cyperus Schweinitzii</i>
<i>Lupinus pusillus</i>	<i>Scirpus americanus</i>
<i>Parosela enneandra</i>	<i>Carex filifolia</i>
<i>Strophostyles pauciflora</i>	<i>Andropogon Hallii</i>
<i>Anogra albicaulis</i>	<i>Sorghastrum avenaceum</i>
<i>Opuntia fragilis</i>	<i>Sporobolus cryptandrus</i>
<i>Opuntia polycantha</i>	<i>Sporobolus asperifolius</i>
<i>Iva axillaris</i>	<i>Bulbilitis dactyloloides</i>

The following species of the Sonoran list extend through the greater part of Transition in North Dakota, most of them being common plants over a large part of the state:

<i>Erysimum asperum</i>	<i>Lomatium orientale</i>
<i>Malvastrum coccineum</i>	<i>Lacinaria punctata</i>
<i>Viola pedatifida</i>	<i>Grindelia squarrosa</i>
<i>Atriplex hastata</i>	<i>Sideranthus spinulosus</i>
<i>Atriplex argentea</i>	<i>Aster oblongifolius</i>
<i>Amaranthus blitoides</i>	<i>Aster multiflorus</i>
<i>Allionia hirsuta</i>	<i>Coreopsis tinctoria</i>
<i>Salix amygdaloides</i>	<i>Bidens frondosa</i>
<i>Salix interior</i>	<i>Artemisia frigida</i>
<i>Rumex persicarioides</i>	<i>Lactuca ludoviciana</i>
<i>Polygonum lapathifolium</i>	<i>Lygodesmia juncea</i>
<i>Androsace occidentalis</i>	<i>Sagittaria arifolia</i>
<i>Solanum triflorum</i>	<i>Typha latifolia</i>
<i>Castilleja sessiliflora</i>	<i>Scirpus campestris</i>
<i>Heliotropium spathulatum</i>	<i>Scirpus atrovirens</i>
<i>Lithospermum linearifolium</i>	<i>Eleocharis Engelmannii</i>
<i>Onosmodium occidentale</i>	<i>Eleocharis palustris</i>
<i>Verbena hastata</i>	<i>Carex gravida</i>
<i>Lycopus lucidus</i>	<i>Andropogon furcatus</i>
<i>Lycopus americanus</i>	<i>Panicum virgatum</i>
<i>Amorpha canescens</i>	<i>Stipa comata</i>
<i>Petalostemon purpureum</i>	<i>Stipa spartea</i>
<i>Astragalus crassicaepus</i>	<i>Calamovilfa longifolia</i>
<i>Astragalus missouriensis</i>	<i>Schedonnardus paniculatus</i>
<i>Glycyrrhiza lepidota</i>	<i>Phragmites Phragmites</i>
<i>Vicia sparsiflora</i>	<i>Distichlis spicata</i>
<i>Gaura coccinea</i>	<i>Puccinellia atroides</i>
<i>Meriopsis serrulata</i>	<i>Elymus Macounii</i>
<i>Onagra pallida</i>	

Of the New Mexican species recorded for Transition the following are common also in the Upper Austral southward from North Dakota (based chiefly upon the writer's knowledge of them in eastern Kansas):

<i>Anemone canadensis</i>	<i>Washingtonia longistylis</i>
<i>Anemone cylindrica</i>	<i>Galium triflorum</i>
<i>Oxalis violacea</i>	<i>Solidago missouriensis</i>
<i>Urtica gracilis</i>	<i>Solidago serotina</i>
<i>Steironema ciliatum</i>	<i>Heliopsis scabra</i>
<i>Apocynum hypericifolium</i>	<i>Carex lanuginosa</i>
<i>Gratiola virginiana</i>	<i>Phalaris arundinacea</i>
<i>Ribes aureum</i>	<i>Muhlenbergia mexicana</i>
<i>Epilobium adenocaulon</i>	<i>Agrostis hyemalis</i>
<i>Epilobium lineare</i>	<i>Sphenopholis obtusata</i>
<i>Sanicula marylandica</i>	<i>Koeleria cristata</i>

*Poa pratensis*  
*Panicularia nervata*

*Filix fragilis*  
*Equisetum arvense*

The remaining few species to be mentioned may be tabulated as follows:

Species	in New Mexico	in North Dakota
<i>Erythraea serpens</i> .....	Lower Sonoran	Enters Transition slightly
<i>Cynops erythrorhizos</i> .....	" "	" "
<i>Polygonum emersum</i> .....	" "	Common through Transition
<i>Dioscoreum trachycarpum</i> .....	Transition to Canadian	Scarcely below Canadian
<i>Carex aurea</i> .....	" " "	Somewhat into Transition
<i>Centaurogrostis canadensis</i> .....	" " "	" " "
<i>Pyrula secunda</i> .....	" " "	In Transition locally
<i>Pyrula elliptica</i> .....	" " "	" " "
<i>Rumex occidentalis</i> .....	" " "	Through Transition generally
<i>Chamaenerion angustifolium</i> .....	" " "	" " "
<i>Hieracium lanatum</i> .....	" " "	" " "
<i>Androsace occidentalis</i> .....	" " "	" " "
<i>Triglochin palustris</i> .....	" " "	Reaches Austral limits
<i>Juncus longistylis</i> .....	" " "	" " "
<i>Calochortus Nuttallii</i> .....	" " "	Near Austral limit only
<i>Rudbeckia laciniata</i> .....	" " "	Through Transition and Austral farther south
<i>Vagnera stellata</i> .....	" " "	Through Transition and Austral farther south
<i>Agrostis hyemalis</i> .....	" " "	Through Transition and Austral farther south
<i>Dasiphora fruticosa</i> .....	Transition to Arctic Alpine	(Noted under "Records of Special Interest")
<i>Viola adunca</i> .....	Transition to Hudsonian	Agrees so far as it occurs
<i>Arctostaphylos Uva-ursi</i> .....	" " "	Mainly Canadian
<i>Oxytropis deflexus</i> .....	Canadian	Canadian
<i>Cirsium alpicola</i> .....	"	"
<i>Corallorhiza multiflora</i> .....	"	"
<i>Alpine longifolia</i> .....	"	Well through Transition
<i>Panicularia borealis</i> .....	"	" " "
<i>Agropyron Richardsonii</i> .....	"	" " "
<i>Agropyron caninum</i> .....	Hudsonian	" " "
<i>Pyrula asarifolia</i> .....	Canadian to Hudsonian	Canadian
<i>Orizopsis asperifolia</i> .....	" " "	" " "
<i>Zygadenus elegans</i> .....	" " "	Well through Transition
<i>Juniperus siberica</i> .....	" " "	Only in southwest at Austral limit
<i>Hierochloa odorata</i> .....	Hudsonian to Arctic Alpine	Through Transition in eastern N. D.

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## LONGEVITY OF THE SEEDS OF CEREALS, CLOVERS, AND TIMOTHY

H. B. SIFTON

This paper is the result of an investigation begun at the Seed Branch, Ottawa, in 1900. The object was to determine the longevity of some of our common crop seeds when kept under favorable and uniform storage conditions. Samples of the cereal crops of 1900, 1901, and 1902, and of the clovers and timothy of 1902 and 1903, were collected. By working with samples of all the standard varieties of the time, collected in successive years from the same farmers, in representative parts of Canada, it was believed that valuable generalizations could be drawn. Four hundred and thirty-eight samples in all were collected. Some of these proved to be too small, and were completely used up before the life of the seed was ended. A sufficient number remain, however, to allow reliable averages to be obtained.

The seeds were stored in cotton sacs or manila envelopes which were kept at ordinary room temperature in a galvanized iron chest with a lid. Once a year, in late summer, they were tested for germination. The records thus permit a comparison of their viability after various lengths of time in storage. The results of tests are recorded in the tables, to which reference will be made as each species is under consideration.

The first results were recorded in 1903, so that in the case of seeds collected in 1900 and 1901 we do not know the percentage germination for the first years. In isolated cases, results of later tests are not available as is shown by gaps in the tables. In calculating averages they have in each case been recorded to the nearest whole number.

### WHEAT

Of spring wheat, forty-seven samples from the crop of 1900, sixty from that of 1901, and sixty-three from that of 1902 were collected. They represent fourteen varieties and were obtained directly from farmers and from the same stock in successive years, grown in representative localities in all the provinces of Canada.

The curve in figure 1 is drawn from the average germination of all these samples for each year of their age. Practically all the kernels retain their vitality for the first five years. Then the weaker ones begin to die, and the curve gradually becomes steeper. More than 75 percent of the seeds lose their vitality between the ages of eleven and fifteen years, and about one half of these die in their 13th year. After the 15th year, the curve begins



turned again. Its direction in the seventeenth year is practically parallel to that in the tenth, and in the eighteenth and nineteenth years its direction corresponds with that in the fifth and sixth years.

When an average sample of wheat is stored for a long period, this investigation shows that its depreciation is divided into three more or less distinct periods. During the first few years (ten or eleven on the average for our Canadian samples), the weak grains gradually die. After this comes the period when the seeds of average vitality (forming the bulk of the sample) die very rapidly. A few seeds, very tenacious of life, are still left, and slowly lose their vitality during the final period of about three years.

It would be interesting for some one who has proper facilities at his disposal to raise plants from the seeds of these three divisions separately, and determine whether there are separate genotypes with different powers of resistance and whether their hardiness is transmitted to the plants which they produce and to their descendants. The work of Crocker and Groves (Proceedings of the National Academy of Sciences, March, 1915) tends to show that the loss of viability is due to the coagulation of the cell proteins, and if this is so it would be unnecessary to wait for years for the seeds to die at ordinary temperatures. Their vitality could be destroyed by carefully regulated heat after the manner used by these investigators.

The results so far considered have to do with total germination percentages as determined by a ten-day test in a standard germinator at alternating temperatures of 20° C. to 30° C. Unfortunately complete records of the preliminary four-day tests, which are believed to give an indication of the energy of germination, are not available. Records of these were kept after the tenth year, however, and are recorded on the graph by means of the dotted curve, which follows a course practically parallel to that of the main curve. During the second period of depreciation the preliminary count is from 6.5 to 8 percent lower than the final count. The energy of germination of a considerable portion of the seeds which are to die during the next year has been weakened. During the third period there is a smaller absolute difference between the two results, but a greater comparative difference; *i.e.*, of the seeds left alive after the end of the second period, the greater proportion have lost most of their energy of germination.

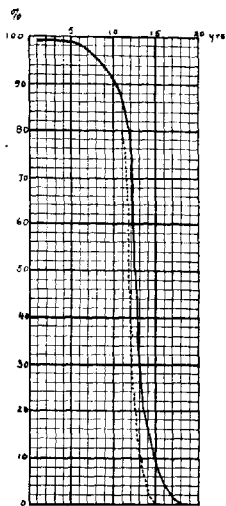


FIG. 1. Longevity curve for spring wheat.

During the first period, if records had been preserved, there is no doubt that we should have found the preliminary and final counts approximating more closely. Although Crocker and Groves, in their work mentioned above, took no account of the depreciation of the seeds after 25 percent of them had died, their results are in agreement with those here obtained. They observe that age lowers the percentage germination and increases the time required for sprouting.

Deviations from the average curve shown in figure 1 are found in some individual cases. An attempt was made to connect these with the meteorological conditions of the year and place of growth. No satisfactory results were obtained, as meteorological statistics for the exact localities where samples were gathered had not been taken.

The variations generally are of two kinds. In very strong samples the tendency is for the first period to be longer, the second shorter, and the division between them much sharper than in average cases. For example, of the Nova Scotia crop of 1902, of which eight samples were investigated (see table 1) 96 percent germinated when twelve years old. After another year only 70 percent were alive, and in three more years the germination was reduced to 9 percent—very slightly above the average for that age. In weaker samples the tendency is toward a flattening of the curve. The Prince Edward Island crop of 1900 and the Ontario crops of 1900 and 1901 are examples of this. Extreme examples are to be seen in the Northwest Territories crop of 1901 and in the Quebec crop of 1900.

No marked difference in longevity has been observed between different varieties.

#### OATS

One hundred and seventy-nine samples of oats were used—fifty-two from the 1900 crop, sixty-four from that of 1901, and 63 from that of 1902. They include thirty varieties.

Their longevity is much greater than that of wheat, possibly owing to the protection of the hulls. 41 percent of the nineteen-year-old kernels are still alive. The longevity curve for the oats differs from that of wheat in two respects. The first period is longer, and the drop in the second period is not nearly so steep, *i.e.*, the kernels live longer and there are more variations in their span of life. In the year 1900, conditions seem to have been less favorable for oats than the normal conditions. The vitality of samples gathered in this year falls off much more rapidly than is the case for 1901 and 1902, and this circumstance makes the second division of the curve in figure 2 considerably steeper than it otherwise would have been. In some cases the 1900 oats start out with a high germination, but in a few years they fall below the crops of other years. Compare for example the Manitoba crops of 1900 and 1902, as recorded in table 2. During the growing season of 1900 the temperature in general was higher than in 1902 when the strongest oats were produced. Slower growth due to low temperature may



have produced hardness, or it is possible that owing to the warmer weather of 1900 more seed was produced by weak strains of plants.

The sample obtained from the Northwest Territories in 1900 germinated in very low proportions even when fresh. This is no doubt to the fact that a cold wave passed over that part of the country in August and in most parts the temperature was several degrees below freezing at some time during the ripening period.

In the majority of cases there is a slight rise in the germination of oats during the first four or five years of storage. While it has been known for a long time that their germination improved during the winter after harvesting, I have seen no account of the continuation of this improvement beyond the first year. The rise is not found in every case. As a rule it is more pronounced in the poorer samples. There is one exception in the Northwest Territories crop for 1901, which germinated in rather low proportions after two years, and from then on showed a gradual decrease.

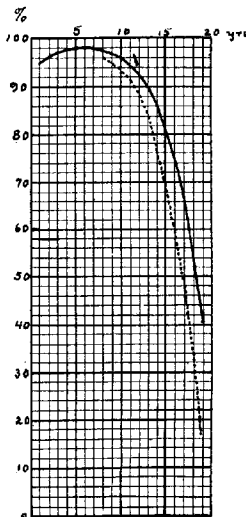


FIG. 2. Longevity curve for oats.

(in 4 days) increases with increasing age.

The tests were carried on at temperatures alternating between 30° C. in the daytime and 20° C. at night. Later experience has proved that these temperatures are not as satisfactory for northern grown oats as temperatures somewhat lower.

#### TIMOTHY

Twenty-five samples of timothy were used for the investigation. Twelve were raised in 1902 and thirteen in 1903.

The curve for these is shown in figure 3. The seed begins to depreciate in value at once, and the life of the strongest kernels is comparatively short. The three periods of depreciation are not marked off so sharply from each other as in the case of hardier seeds. The germination begins to fall off rapidly after the seventh year, when it is 84 percent. By the twelfth year it is reduced to 11.5 percent, and after that the curve flattens again until at seventeen years of age the seed is practically all dead.

No records of preliminary counts were kept until the tenth year, when only 54 percent of the seed was left alive, and such as are available are therefore of little or no value.

TABLE 3. *Germination of timothy at different ages*

No. of Samples	Year of Growth	1 Yr. Old	2 Yrs. Old	3 Yrs. Old	4 Yrs. Old	5 Yrs. Old	6 Yrs. Old	7 Yrs. Old	8 Yrs. Old	9 Yrs. Old	10 Yrs. Old	11 Yrs. Old	12 Yrs. Old	13 Yrs. Old	14 Yrs. Old	15 Yrs. Old	16 Yrs. Old	17 Yrs. Old
12.....	1902	97	96	91	96	90	87	83	74	63	58	24	7	2	3	1	1	0
13.....	1903		93	94	92	90	86	85	81	72	52	23	13	14	5	3	2	0
Average....		97	94	93	94	90	86	84	77	68	54	23	10	8	4	2	1	0

TABLE 4. *Germination of alsike at different ages*

No. of Samples	Year	1 Yr. Old	2 Yrs. Old	3 Yrs. Old	4 Yrs. Old	5 Yrs. Old	6 Yrs. Old	7 Yrs. Old	8 Yrs. Old	9 Yrs. Old	10 Yrs. Old	11 Yrs. Old	12 Yrs. Old	13 Yrs. Old	14 Yrs. Old	15 Yrs. Old	16 Yrs. Old	17 Yrs. Old
12.....	1902	93	90	85	84	79	70	67	54	49	45	34	14	18	17	20	19	19
12.....	1903	93	92	91	87	81	77	72	65	63	45	25	28	29	30	24	30	19
Average....		93	91	89	85	80	73	70	60	56	45	29	20	23	24	22	24	19

TABLE 5. *Germination of red clover at different ages*

No. of Samples	Year of Growth	1 Yr. Old	2 Yrs. Old	3 Yrs. Old	4 Yrs. Old	5 Yrs. Old	6 Yrs. Old	7 Yrs. Old	8 Yrs. Old	9 Yrs. Old	10 Yrs. Old	11 Yrs. Old	12 Yrs. Old	13 Yrs. Old	14 Yrs. Old	15 Yrs. Old	16 Yrs. Old	17 Yrs. Old
12.....	1902	97	93	86	80	77	65	61	57	48	44	27	7	15	11	14	8	9
12.....	1903	96	96	92	86	75	68	68	59	59	43	17	21	29	28	16	23	9
Average....		96	94	90	83	76	66	65	58	54	44	22	14	23	18	15	17	9



### ALSIKE AND RED CLOVER

Twelve samples of each of these from the 1902 crop and twelve used in 1903 were used, and the tests were carried on at 18° to 20° C. The curves

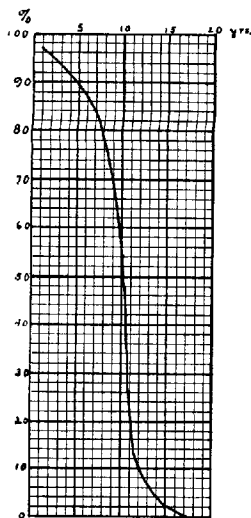


FIG. 3. Longevity curve for timothy.

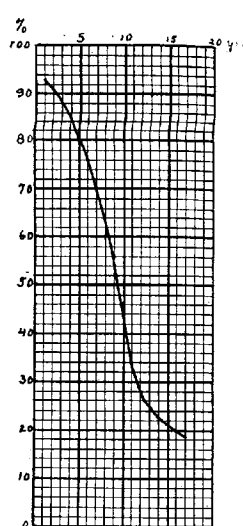


FIG. 4. Longevity curve for alsike.

are shown in figures 4 and 5. The interesting thing about them is their regular decline from the first, making each curve, as far as it has yet gone, approach a straight line much more closely than in the case of any other crop studied. Both clovers have a larger proportion of long-lived seeds (over 15 years) than wheat, but from the standpoint of a practical seedsman their longevity is not nearly so great. After eleven years, wheat on the average still germinates to the extent of more than 85 percent, but eleven-year-old alsike or red clover seed germinates less than 40 percent. (This result is calculated from the curve. The actual germination obtained in the laboratory on eleven- and twelve-year-old samples was much less, but the results of later and earlier tests make it evident that the percentages obtained in these two years were not correct.)

The natural expectation would be that the curves for the clovers would be almost horizontal at the first owing to the gradual softening of "hard seeds" with age. This, in the course of an experiment not yet ready for

permeation, has been proved to be true in alfalfa. The samples contained

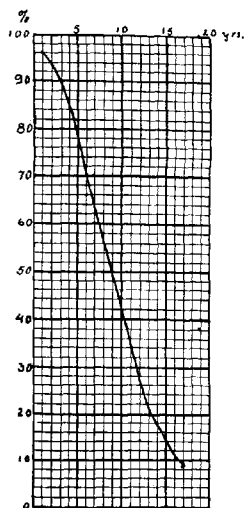


FIG. 5. Longevity curve for red clover.

a considerable proportion of "hard seeds," and for a few years the germination percentage increased as they became permeable.

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## ON THE ANATOMY OF *CHENOPODIUM ALBUM* L.

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### INTRODUCTION

The Chenopodiaceae and related families exhibit a most striking anomalous structure of the stem in that the annual secondary thickenings contain several circles of collateral vascular bundles of limited development which are embedded in lignified so-called "conjunctive tissue."

Gheorghieff (1) in a series of publications gives a detailed review of the early literature on this subject. His own contributions, furthermore, comprise the most comprehensive study of the anatomy of the Chenopodiaceae. He finds that the plants which he examined show greatly varied forms, transitional in structure to many of the Centrospermae.

Sanio (2) in 1863 gives the most complete ontogenetic study of members of the Chenopodiaceae. He attributes the anomalous structure of the stem to the activity of a periodically acting cambium which produces collateral vascular bundles and "conjunctive tissue." At the conclusion of his work Sanio draws a comparison between the anomalous stem structure of the Chenopodiaceae and the stem structure of those monocotyledons which are characterized by growth in thickness.

In his "Comparative Anatomy of the Phanerogams and Ferns," De Bary (3) develops a theory to account for the diverse forms of anomalous growth of the vascular tissue of Chenopodiaceae and related families. He makes four general classes. In the plants of the first group, an extrafascicular cambium appears around the primary ring of leaf-trace bundles. This cambium remains permanently active and forms alternately on its inner side collateral vascular bundles and conjunctive tissue; on its outer face it forms a thin layer of phloem or none at all. The plants of the second type develop a ring of primary vascular bundles with normal cambium. The activity of the latter soon ceases, and on the outer face of the primary ring appear in centrifugal order a succession of cambia each of which forms a distinct ring of vascular bundles and intermediary tissue. Classes three and four are types intermediate between the first two.

Morot (4) points out that the two modes of growth described by De Bary may be reduced to one type. The cambium in each case retains its bipolarity, giving rise to xylem on the inside and phloem on the outside.

Fron (5) subsequently states that the stem of *Chenopodium album* increases in diameter by the activity of a normal and pericyclic cambium, and that this cambium produces to the inside xylem and parenchyma and to the outside phloem tissue.

However, notwithstanding the comparatively large amount of work done on the inner structure of the Chenopodiaceae, the origin of the intraxylary phloem, its relation to the cambium and to the xylem of the bundles, remained obscure. It was therefore the primary object of this investigation to study the relation of cambial activity to the development of anomalous growth. It was also hoped to extend our knowledge of the histology of the vascular tissue, in particular that of the phloem.

#### MATERIAL AND METHODS

The work was begun during the summer of 1919 at Ft. Lewis, Colorado, and was completed at the Department of Botany, Cornell University. Material taken from the field was studied while fresh. It was found most satisfactory to use unstained hand sections for both anatomical and ontogenetic studies. This method has an obvious advantage over most modern laboratory practice in that it permits the examination of a large amount of material in all stages of development with the least expenditure of time. But for the purpose of checking results and for use in making photomicrographs, representative material was killed in Flemming's weaker solution, embedded, some in paraffin, some in celloidin, sectioned, and stained in the usual manner.

#### ANATOMY

A transverse section of a young stem shows between pith and cortex a circle of separate bundles—the leaf traces. Their number varies, there being even in very young stems as many as twenty. The largest of these traces belong to the lower leaves, the smallest to the primordia of the leaves near the growing apex.

These primary leaf-trace bundles are collateral. The phloem in cross section is a compact oval or oblong mass of tissue (Pl. XVI, A), bounded externally and laterally by parenchyma cells which, when still young, contain chloroplasts. The xylem also is definitely set off from the surrounding fundamental tissue. Its first-formed elements are scattered, and only the later formed metaxylem and the secondary elements show a definite arrangement in radial rows. In older sections we notice the development of an interfascicular cambium uniting individual leaf-trace bundles of the primary cycle, and an extrafascicular cambium from which originates a series of collateral bundles and conjunctive tissue. This tissue later lignifies and, together with the xylem of the bundles, forms a compact woody cylinder in which appear embedded small islands of phloem. The origin of this intraxylary phloem and of the conjunctive tissue, together with changes which take place when the tissues mature, will be discussed under the heading "Ontogeny."

No true secondary phloem develops; the true phloem remains restricted to the bundles in a given cycle. A narrow band of pericycle, sometimes

only a ring of fibers, separates the vascular cylinder from the cortex. The cortex itself is of only limited extent and rarely more than two to four cells wide. The outer cortex is differentiated into collenchyma and photosynthetic tissue. The former occupies the ridges of the stem while the latter is found in the intervening spaces. The one-celled epidermis is of two types: the epidermal cells external to the collenchyma are elongated and their tangential walls are thickened; those external to the photosynthetic region are thin-walled and nearly isodiametric.

The collenchyma cells are long, pointed, and thickened at the corners only and communicate with one another by simple pits. The cortex and pith are made up of thin-walled, loosely connected parenchyma cells in which are often found druses of calcium oxalate (Pl. XVII, B).

Occupying the periphery of the vascular cylinder is a ring of fibers the elements of which are of the usual type but vary in size and diameter of lumen. They are rarely completely united into a closed ring but rather form short bands one to several cells wide. In places the cells of the phloem elements of the vascular tissue abut directly on the fibers; most often, however, a narrow band of pericyclic tissue intervenes.

The elements of the vascular cylinder are in general of advanced dicotyledonary types. The frequent occurrence of transitional forms in xylem and intermediary tissue makes the study of this group of plants especially interesting.

The xylem is made up of porous vessels, fibers, and wood parenchyma, the last named being vasicentric. The vessels are of two general types (Pl. XVI, C). The large type, most commonly arranged in uniseriate radial rows (Pl. XVI, B), is rectangular with end walls nearly transverse. The small type of vessel shows less definite arrangement; it is more elongated and its end walls are always more or less oblique. The walls of the vessels are heavily pitted. The pits are small, pentagonal, and arranged in alternate rows (Pl. XVI, C, G). In the small type of vessel, however, the pits may not show the symmetrical form and regular arrangement.

The fibers approach the libriform type. The elements are long and pointed but comparatively thin-walled. The walls are but sparingly pitted. The longitudinal course of the fibers is not absolutely straight in that the ends of the elements diverge obliquely whereby they become partly interlocked, which arrangement gives the wood an especially great toughness.

In the xylem of the leaf-trace bundles we find in addition to the types of elements just described the typical elements of the protoxylem with transition forms to the pitted vessels. The first formed elements of the protoxylem are narrow; the secondary thickenings of their walls are of the nature of loose spirals and wide rings (Pl. XVI, E). Much protoxylem, however, is made up of larger elements with secondary thickenings in the form of close spirals. Gradually the arrangement of the elements becomes more definite. The type of element also changes, and instead of close

spiral, we now find elements with scalariform and sometimes with reticulate walls. Various types of transitional forms are found between the spiral element on the one hand and the pitted vessel on the other. The metaxylem, and of course the wood produced by the cambium, contain only pitted vessels.

The xylem, as we have learned, forms a compact woody cylinder made up of a series of concentric, undulate zones of growth (Pl. XVI, *B*), each zone in turn being a circle of collateral vascular bundles united with one another by intermediary or conjunctive tissue. Separating each zone of growth is a tangential band of parenchymatous tissue of varying width. Narrow, or sometimes broad, bands of parenchyma traverse the xylem in radial direction. These bands usually connect radially the individual zones of growth. Often, however, they pass through several zones, and in those instances closely resemble medullary rays.

In cross section the cells of this conjunctive tissue appear like ordinary parenchyma, but in radial and tangential cuts a great variation in form manifests itself. There are groups of cells made up of the common substitute fiber—a tracheidal element with simple pits. Other elements of this tissue are comparatively short or even isodiametric. Morphologically, then, this tissue is not homologous with rays, though it may function as such.

The phloem is made up of three types of elements: the sieve tube, the companion cell, and the phloem parenchyma. Contrary to the conclusion of earlier investigators (1, 4), the sieve tube is the principal element of this tissue. The tubes form longitudinal series (Pl. XVI, *D*) with occasional anastomosing of the elements of closely connected groups. On the whole, however, the course of the phloem groups is radial-perpendicular, with connections of the elements of the groups taking place only through the leaf gaps formed by the branching of the leaf-trace bundles and their subsequent fusion.

The sieve tube is of medium size with an average diameter of  $14\mu$ . The end walls are usually slightly oblique, which makes it difficult to observe the sieve plates in strictly transverse sections. There are no sieve plates in the radial walls. The latter, however, are extensively pitted with the companion cells, which, as is usually the case, are connected by simple pits with the neighboring parenchyma cells of the conjunctive tissue. Late in the season the plates of many sieve tubes become covered with callus; this callus formation is most often observed in the phloem of the primary bundles.

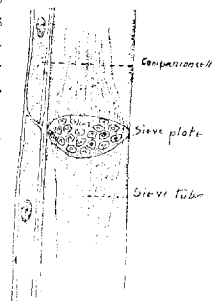


FIG. 1. *Chenopodium album*:  
Diagrammatic drawing of sieve  
tube and companion cell.

## ONTOGENY

Almost immediately below the growing point the procambium becomes distinct, forming a concentric band of tissue between cortex and pith. At certain points in this procambium the primordia of vascular strands appear recognizable as such by the small size of the elements and by their granular content. The smallest primordia contain only elements of the phloem. Slightly older groups also contain elements of the protoxylem. The first formed phloem cells are thin-walled, very narrow, and take the typical haematoxylin stain. Sieve tubes become distinct in mature sections only. The protoxylem elements are also narrow and of the loose spiral type (Pl. XVI, E). The groups of phloem and xylem are at first separated by undifferentiated procambium. With enlargement of the group, a cambium develops which later initiates secondary growth.

The procambium surrounding the strands of vascular tissue undergoes active division, causing the primary bundles to become separated and initiating the formation of new bundles in the widening spaces. These new bundles naturally do not extend so far into the pith (Pl. XVII, D), and, like the primary bundles, they increase in size through the activity of a cambium.

Gradually the procambium cells between the vascular groups cease dividing. All the elements mature except a single layer which remains meristematic, and which, as an interfascicular cambium, unites the separate bundles into a vascular ring. This cambium layer appears at first only between the larger groups, while later the smaller and more distant groups may also become united to form a part of the primary cylinder.

During the enlargement of the primary bundles an extrafascicular cambium appears (Pl. XVII, A, C) in the still undifferentiated procambium on the outer face of the primary bundles. This layer of meristematic cells is not formed simultaneously in a given circle, and as a consequence,

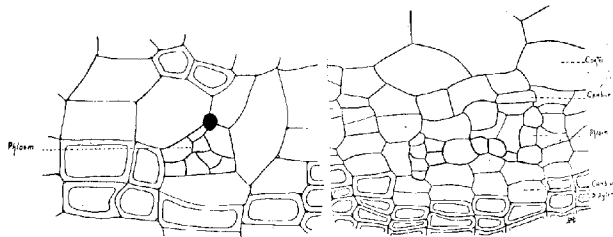


FIG. 2. *Chenopodium album*: Drawings illustrating the mode of origin of the intraxylary phloem. A, transverse section of stem showing cambium cells dividing in different planes, forming eight cells which become the phloem of the vascular ring. B, transverse section of stem showing the appearance of a new cambium in the parenchyma adjacent to the newly formed phloem groups.

different parts of the ring are found in different stages of development. This condition results in the formation of an undulate circle of cambium. In this cambium, cell division takes place only centripetally, resulting in the formation of a cylinder of tissue consisting of alternate radial segments of xylem and of conjunctive tissue. The cells of this secondary xylem, the large vessels in particular, are arranged in radial rows, differing therein from the primary tissue in which the elements are without any definite arrangement.

After a limited period of activity, certain areas in the cambium, chiefly opposite the large primary bundles, undergo a change of function. One or two cambium cells divide rapidly in different planes forming from two or three to ten cells (fig. 2, *A, B*; Pl. XVII, *E, F*).

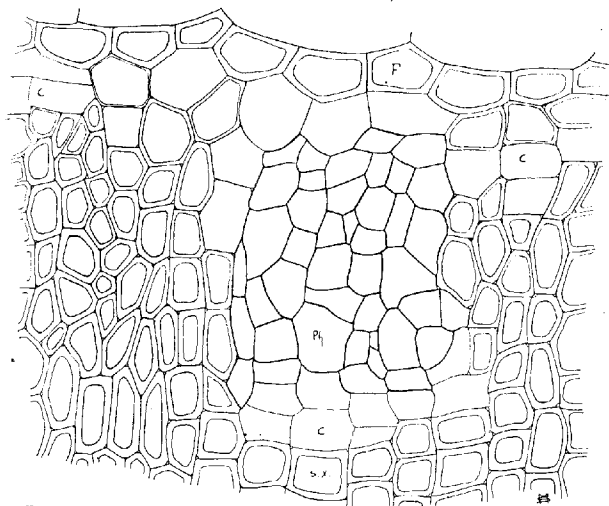


FIG. 3. *Chenopodium album*: Transverse section of stem showing mature phloem group. The appearance of the new cambium segment above the group is belated. The cambium at either side of the phloem group has divided very actively and has thus caused the phloem to be completely embedded in xylem. (*C*, cambium; *F*, fibers; *Ph*, phloem; *s.x.*, secondary xylem.)

These cells become the phloem of the just-formed vascular ring. We thus have a ring of xylem with segments of parenchymatous conjunctive tissue with a number of separated phloem strands on the outside. Occasionally the portions of cambium behaving in this manner are not used up in this process but may form a small amount of xylem toward the inside after the completion of phloem formation. These segments of cambium disappear,



as such, since they mature into vascular tissue. The ring of cambium is thus broken up.

The cells of the cambium which are not concerned with the formation of these phloem groups are dividing very actively meanwhile, so that the cambium ring becomes undulate, the phloem groups occupying the depressions. Very soon after the initials of these phloem groups appear, a cambium forms in the parenchyma adjacent to the outer face of these groups (fig. 2, *B*). This new cambium becomes connected laterally with the cambium ring of the vascular cylinder. Sometimes the appearance of these new cambium segments is belated, and not until the unequal activity of the cambium ring has produced the undulate appearance and the depressions does a cambium layer appear at the outer face of each new group (fig. 3). In such a case the cambium formation begins at the margin of the depression, advances laterally, and when united undergoes reciprocal tangential division, thus giving rise to xylem and parenchyma which mature in the normal manner.

The formation of new cambium initials which mature into groups of phloem completes the growth of a zone of thickening which is succeeded by a new similar zone. The same process is repeated, and thus arise the undulate zones of vascular tissue so characteristic of the members of the Chenopodiaceae.

#### CONCLUSIONS

The study of the anatomical features of the vascular tissue of the stem in part confirms and in part modifies and extends the results obtained by earlier investigations. In the discussion of the histological features of the phloem it was shown that sieve tubes and not phloem parenchyma make up the larger portion of that tissue. Why earlier investigations limit or even deny their occurrence is hard to understand. Even Gheorghieff in his detailed anatomical researches of the group simply states: "Die Phloempartie ist vorwiegend aus parenchymatischen Elementen zusammengesetzt. Siebröhren habe ich nur selten gefunden." It must be admitted, however, that the elements of the phloem are comparatively small, and that the sieve tubes especially are narrow and easily mistaken for plasma-rich cambiform elements unless staining reactions show the sieve plates or the callus deposits over the plates. The typical staining reaction of this substance is a further aid in identifying the sieve tubes.

The elements making up the conjunctive tissue exhibit such a variety in form and arrangement that they could not be conceived of as ray cells in the morphological sense. That they may function, however, as rays is not at all unlikely.

Above all, however, this study has shown that the anomalous growth of the stem is produced by a periodically acting cambium which is progressively renewed at places where new phloem groups originate. In the

development of each individual zone of growth, the xylem of the bundle is formed first, its formation being followed by a change in the activity of the initial strand on the outer face of the cambium; from the active division of this strand the phloem is produced. There is little if any new xylem added to the vascular ring in those places where phloem initials originate, for the xylem of the bundles, as has already been shown, is developed before any of the phloem matures. The cambium then does not exhibit the unipolarity which De Bary claimed for the group to which *Chenopodium album* belongs; it is always bipolar in restricted regions in that it gives rise to normal tissue elements on either side.

## SUMMARY

1. The anomalous stem structure of *Chenopodium album* is produced by a periodically active cambium which forms xylem centripetally throughout its extent and phloem centrifugally in restricted regions. Where phloem is formed the cambium is "used up." The continuity of the cambium ring is maintained by the formation of new portions outside the phloem groups.
2. The phloem of a secondary zone of growth is produced after all or most of the xylem has been formed. It is the normal product of the cambium and only belated in its development.
3. The intermediary or conjunctive tissue is not ray tissue in the morphological sense though it may function as such.
4. The chief element of the phloem is the sieve tube with its companion cell. Phloem parenchyma is of only secondary importance.
5. The stem structure shows in its ontogeny a striking similarity to the structure of the root of the sugar beet, a developmental study of which is contained in De Bary's "Comparative Anatomy."

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## EXPLANATION OF PLATES

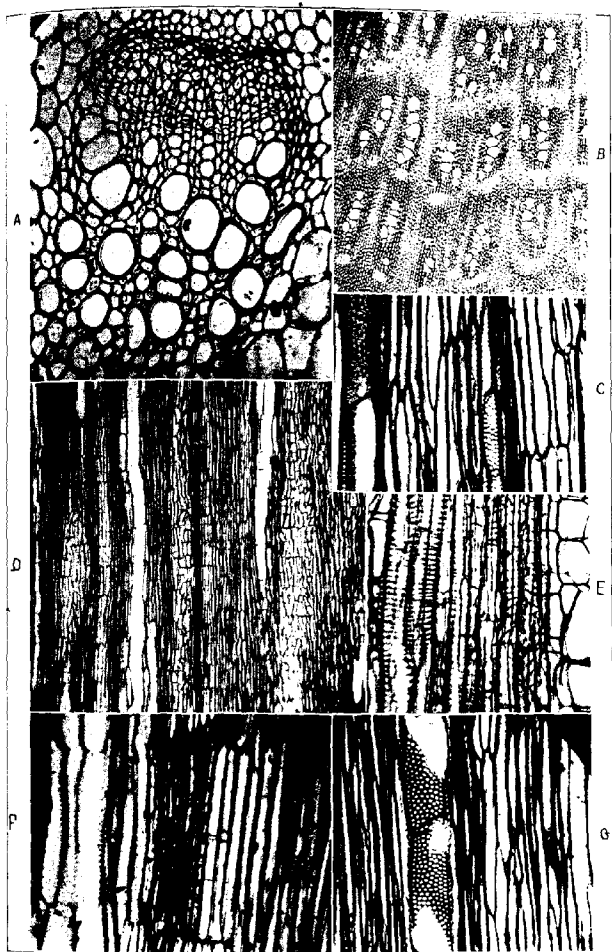
## PLATE XVI

- A. Cross section of a large primary bundle showing arrangement of primary and secondary xylem; position and extent of phloem groups.
- B. Cross section of part of mature stem showing undulate appearance of the zones of growth; extent and position of the conjunctive tissue and the radial arrangement of the large vessels.

- C. Longitudinal section of xylem showing both types of vessel.
- D. Radial section of stem showing size and longitudinal course of the phloem.
- E. Radial section of primary xylem showing spiral and ringed elements.
- F. Radial section of phloem showing the sieve tubes with companion cells and phloem parenchyma.
- G. Radial section of xylem showing (from left to right) fibers, vessels, and connective tissue.

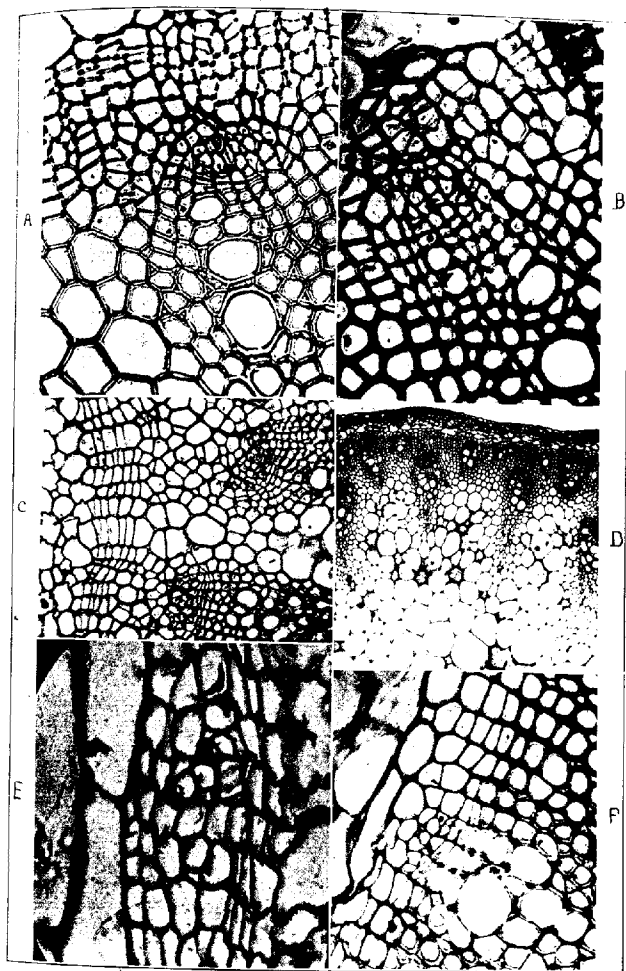
## PLATE XVII

- A. Cross section of part of young stem showing the appearance of an extrafascicular cambium above a phloem group.
- B. Cross section of a more mature stem showing the same condition as in A. Druse of calcium oxalate in cell of cortex.
- C. Section of primary bundles of stem. Above the bundles an extrafascicular cambium has developed which is several rows wide.
- D. Cross section of young stem showing several primary bundles and the first zone of thickening.
- E. Section of vascular strand initial. Extrafascicular cambium has developed above, the newly formed phloem group.
- F. Section through annual zone of growth showing the development of an initial strand of phloem.



ARTSCHWAGER : ANATOMY OF *CHENOPODIUM ALBUM*.





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